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THE LYRIFORM ORGANS AND TACTILE HAIRS OF ARANEADS.

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INTRODUCTION AND METHODS.

Since the discovery of the lyriform organs in 1878 only two important papers have appeared in regard to them. The object of this present paper has been to make an accurate and careful study of their morphology and physiology. The tactile hairs were later taken up in connection with the lyriform organs because their innervation was very similar to that of the latter structures.

The work has been prosecuted under the direction of Professor Montgomery, to whom I am indebted not only for the majority of my specimens, but also for suggestions and kindly criticisms which have made this work possible. He suggested this subject because these organs are so little known. The exotic species were kindly sent by Dr. Purcell, of South Africa; by Dr. Petrunkevitch, of Yale University, and by Mr. Nathan Banks, of the U. S. National Museum. The

experimental work was done at the Marine Biological Laboratory at Woods Hole from June 7 to September 20, 1910.

In regard to the methods for preparing sections, after the legs had been removed from the spiders, they were cut into short pieces and then were fixed a few hours in either strong Flemming's solution or in Carnoy's fluid, the latter being the modified form of equal parts of absolute alcohol, glacial acetic acid and chloroform with corrosive sublimate to excess. Carnoy's fluid was the better of the two fixatives and my best sections were obtained by leaving the material in the fluid over night. The material was dehydrated in the ordinary way in alcohols but was cleared by using the sinking method in cedar oil. It was embedded about an hour in hard paraffin (54° C.). On account of the hard cuticula perfect serial sections were impossible, although good sections were had in two ways: (1) After fixation the material was left in a solution of equal parts of 70 per cent. alcohol and glycerin two or three weeks; (2) The material was fixed immediately after moulting. The latter method was the better one for the cuticula was very soft and thin. The sections were cut ten microns thick and were stained with Delafield's hæmatoxylin and eosin.

In preparing the external surfaces for the study of the disposition of the lyriform organs the following method was pursued: A large slit was made on the dorsal side of the abdomen of the specimens, then they were dropped into a cold solution of caustic potash. In this solution the adults remained from six to thirty-six hours, the time depending on the size of the individual; for the spiderlings one hour was sufficient time. After being removed from the caustic potash solution all the internal disintegrated tissues were carefully removed with a camel's hair brush and water. Now the "skins" were permanently mounted between two cover slides in a one-fifth saturated solution of potassium acetate. Such a solution gave the proper refractive index so that the slits appeared more or less transparent while the surrounding cuticula was usually darker. The two cover slides were held together with a solution of asphaltum. For the dark colored specimens bright day light was used, but for the light colored ones a strong yellow artificial light was the only one which was satisfactory.

A. THE LYRIFORM ORGANS.

I. MORPHOLOGY.

1. *Structure of Lyriform Organs.*

A lyriform organ is a cuticular structure peculiar to arachnids, composed usually of several single slits which lie side by side and

more or less parallel with each other. This group of slits is generally surrounded by a border (fig. 53b)¹, which is nothing more than a difference in pigmentation, that gives the lyre-shape to the organ. Inside the border the pigmentation is usually much lighter than outside, but sometimes the reverse occurs. Hence with considerable magnification these organs appear as light or dark spots while the slits inside appear almost transparent. The superficial appearance of a slit reminds one of a long slightly bent spindle which has an opening or dilatation (di.) at the centre or nearer one end than the other (fig. 53).

Lyriform organs may be divided into compound and simple organs. A compound organ contains four or more single slits, which may either be enclosed by a common border or each slit may be surrounded by its own border; in the latter case if the borders are not joined with each other, then the structure may be called a diffused organ; sometimes the border is entirely absent. A compound organ never exceeds more than thirty slits and the average for *Theridium tepidariorum* is ten, but the number containing four, five or six is comparatively small. A simple organ contains either two or three single slits, around all of which there is a common definite border.

A cross-section of a lyriform organ shows that it may sometimes be located on a slight elevation or at other times in a slight depression, but in either case the cuticula at this place is considerably thicker and sometimes twice as thick as at other places. Fig. 1 shows this very well. This drawing represents about one-third of the entire cross-section of the trochanter of a mature male *Agalena nævia* just moulted. The cuticula (cu.) is only diagrammatic as taken from various species, but here its thickness represents its greatest development at any time in this species. The nerve (N.) is drawn in the location it holds when its branch (N. b.) penetrates the hypodermal basement membrane (b. m.), 220 microns in front of this locality where the nerve branch just begins to leave the nerve the latter is much nearer the centre of the leg. The sense cells (s. c.) are shown in their natural positions but they have been reconstructed from nine sections just in front of where the nerve branch enters the hypodermis. All the other parts are taken from only one section in front of the organ. In this drawing one notices that some of the slits pass entirely through the cuticula, some two-thirds through, and others show only a slight indentation. This means that the section passed exactly through

¹The figures are numbered consecutively on Plates XXX-XXXIII.

the dilatation in the case of the first, near the dilatation of the second, and only across the ends of the slits in the last. Hence the deeper the opening the nearer the section passed to the dilatation. Thus the internal cavity of a slit may be represented by the diagram (fig. 4), which shows it to have the form of a flattened funnel with a central enlargement. At least three distinct layers are discernible in the cuticula, but they are not shown in fig. 1.

The hypodermis (hyp.), usually twice as thick as the cuticula, lies just beneath the latter. Its long cylindrical cells stand at right angles to its outer membrane (o. m.) and to the basement membrane (b. m.). The outer membrane is very thin and never shows any nuclei, while the basement membrane is much thicker and reveals several elongate nuclei (b. m. n.). Directly beneath and on either side near the organ these hypodermal cells appear to be vacuolated at their bases, while at some distance from the organ they are not vacuolated. With Delafield's haematoxylin and eosin the cell walls and cytoplasm stain very faintly, but the nuclei stand out very conspicuously, and nucleoli are very numerous. There are always just as many sense cells (s. c.) as there are slits in the organ; if the slits are few in number the sense cells lie at the base of the hypodermis directly beneath the organ. If the slits are many then there is not enough space just beneath the organ, so the sense cells are scattered along the basement membrane of the hypodermis toward the nerve as seen in the drawing. Each sense cell is always as large and sometimes three times as large as any hypodermal cell. It is invariably spindle-shaped with one of its poles running to the nerve of the leg and the other pole connecting with the dilatation (di.) of its respective slit. The nuclei are usually two or three times as large as those of the hypodermal cells and stain slightly darker, although sometimes both kinds of nuclei have the same dimensions and degree of staining capacity when it is difficult to distinguish the two kinds of cells unless one can readily see their walls. Moreover, most sense cells have at least at one end of their nuclei aggregations (ag. cyt.) of dense staining cytoplasm, which does not occur in the hypodermal cells. Also each sense cell has at least one very large nucleolus besides the numerous smaller ones and its cytoplasm stains slightly darker. Therefore, when we consider all these differences, we see that the sense cells are different from ordinary hypodermal cells, but since in many cases these differences are very difficult to distinguish, as with those small sense cells just beneath the organ in the drawing, we must conclude that sense cells are nothing more than modified hypodermal cells which have taken on a different

function. In the specimens just moulted the sensory fibers were never connected with the dilatations (di.) of the slits, merely because they apparently had not had sufficient time for regeneration since the casting of the old skin. But in specimens six or seven hours after moulting a few of these connections were noticed, while in individuals with thick cuticula many such connections were observed. Fig. 3 shows two of these sense cells as they actually occur in a section of the trochanter of *Th. tepidariorum* six or seven hours after moulting. Here the cuticula is broken as usual, but one nerve fibre connects with its dilatation, the other one has either been broken loose or has not yet had time to join its dilatation since moulting.

In good serial sections the nerve of the leg is very distinct and branches from it can very readily be traced to the lyriform organs. Within these branches the nerve fibres can quite easily be traced to the sense cells. Usually the nerve is found near the axis of the leg, but in some cases it lies closer to the hypodermis as shown in fig. 1. Both the nerve and its branches are enclosed by a neurilemma (neu.) whose walls show numerous nuclei (n. neu.). Internal to this neurilemma the fibres are shown in cross section as the clear spaces with here and there a cross section of a tolerably deep staining nucleus, probably a neuroglia nucleus (neu. n.). These nuclei are about one-third as large as those of the hypodermal cells; their nucleoli are generally arranged around the periphery and their chromatin-network as in the other kinds of nuclei is rather difficult to see. The network (neu. w.) of the nerve is probably the walls of these neuroglia cells.

I was able to trace the innervation of a few of the single isolated slits. Fig. 5, drawn from two consecutive sections of *Th. tepidariorum* six or seven hours after moulting, shows the sense cell with its fibre connecting with the dilatation of the slit. This cell has a similar position, shape, size and structure to one of those belonging to an organ.

At certain places in the legs the muscles occupy almost all the space surrounded by the hypodermis, but generally near the lyriform organs they are not so extensive. At almost any place one may choose at least three or four such muscles (m. b.) as the one shown in the drawing may be readily seen. The single walled sarcolemma (sar.) surrounds many muscle bundles, each one of which reveals either two or three nuclei (m. nuc.) lying in the sarcoplasm.

Each leg possesses a large artery (art.) which usually lies against or near the nerve. It has a double wall which often shows nuclei. Two large venous sinuses (v. sin.) are always present, one on the

ventral and the other on the dorsal side. In fact each one seems to lie directly beneath a lyriform organ. The blood plasm (b. p.) and blood corpuscles (b. c.) can readily be distinguished in both the artery and sinuses.

The connective tissue (con. t.) which stains very faintly occupies all the remaining space in the leg. Its nuclei (con. t. n.) which are very conspicuous are about one-half as large as those of the hypodermis.

Fig. 2 is a longitudinal-transverse diagram of the distal end of a femur showing the anatomy of the leg with the innervation of the lyriform organs, the fixed tactile hairs (t. h.) and the muscles which control the movable tactile hairs (mov. h.).

2. Disposition.

(a) *Theridium tepidariorum* Koch.

In making a comparative study of the lyriform organs of Araneads, I have used thirty-nine different species representing twenty-seven of the thirty-eight families recognized by Simon (1892). Since *Th. tepidariorum* is most conveniently studied, I shall describe its lyriform organs in detail and then state the variations found in the other species after the explanation of the table on page 394. See figs. 13 and 14.

The legs and palps may be divided for description into four surfaces. The organs, to begin with the one on the coxa of each leg and palp, may be numbered from 1 to 13 with No. 13 on the metatarsus of each leg. In *Th. tepidariorum* there is a constant number of thirteen organs on each leg; four of this thirteen are on the dorsal, three on the posterior, two on the anterior, and four on the ventral surface. Each palp has only seven organs, three of which are on the dorsal and the other four are on the ventral surface. Each cheliceron has a constant number of four organs, No. 14 and 15 of which lie on the ventral and No. 16 and 17 on the dorsal surface. There is always a constant number of two organs located on the dorsal side of the pedicle, one of these may be called No. 18. The single isolated slits are found more or less regularly distributed on all the appendages, sternum, cephalothoracic shield and on the ventral side of the abdomen (figs. 13, 14).

Every organ has a constant position except the three on the trochanter and the one on the coxa. The latter organ occurs either on the ventral or posterior side of the joint. The organs on the trochanter rotate around the segment and sometimes the same organ

may be found on either the ventral or dorsal surface in two different legs as organ No. 2 on the first and third leg (figs. 13, 14). Organ No. 3 may occur on either the anterior or posterior side of the trochanter as on the second and first legs. Also No. 4 may lie on either the dorsal or ventral surface as in the first and third legs.

Organ No. 1 (figs. 13, 16) is a simple structure of three slits on the first three legs while on the fourth there are only two slits in it. These slits have about the same dimensions and the dilatations are nearer the proximal end of the organ. The distal end of the slits never come in contact with the line of articulation. No 2 varies slightly in shape, number and position of the slits. In fig. 52 the organ is from the ventral side of the first leg, while in fig. 53 the organ from the anterior side of the second leg shows the slight variation. The distal end never crosses the line of articulation. No. 3 is more or less diffused (fig. 15), but on the first and second legs the border completely surrounds the organ. Instead of the long axis of No. 4 lying parallel with the long axis of the leg, it lies transversely (fig. 30) and it always lies against the line of articulation and sometimes one-half way across it. No. 5 on the ventral surface at the extreme distal end of the femur always lies with its distal end touching the line of articulation, but very seldom crosses it. The convex part of the organ and the shorter slits invariably face the posterior surface of the leg (figs. 13, 24). No. 6 is like No. 5 except it lies on the dorsal side of the femur and usually one-half way across the line of articulation (fig. 14). Its concave side and shorter slits face the anterior surface of the leg. Organs No. 7 and 8 (figs. 13, 14, 58) are always found on the anterior surface of the patella. No. 7 (58a) lies almost equidistant from either end of the joint near No. 8 (58b) and always between the latter and the dorsal side. Its size is almost one-half that of No. 8 and its slits are very long and extremely narrow. No. 8 lies nearer the distal end of the patella, usually very near the line of articulation, but never against it. Its slits are much longer than those in No. 7 and the smaller ones face the ventral surface as in No. 7. One finds organ No. 9 at the distal end of the patella on the dorsal side about 135 degrees from organ No. 7. It never touches the line of articulation and is usually some distance from it. Its apex points toward the angle formed by the line of articulation with the edge of the anterior side. Its shorter slits always face the anterior surface of the leg. One or two or no single isolates slits usually accompany it and these occur near the concave side which faces the anterior

surface of the leg (figs. 14, 18). Nos. 10 and 11 (figs. 13, 57), like Nos. 7 and 8, are paired, and they occur on the ventral surface at the extreme distal end of the tibia. No. 10 lies mostly across the first line of articulation (1. l. a.) with its apex pointing toward the articulation. Its shorter slits always face the anterior surface of the leg and it invariably lies between this surface and organ No. 11. The latter organ lies only slightly over the first line of articulation with its apex directed from the articulation. Its shorter slits face the anterior surface of the leg or exactly toward the apex of No. 10. Organ No. 12 lies at the extreme distal end of the tibia on the dorsal surface at the edge of the anterior side. It lies two-thirds across the first line of articulation with its apex touching the second line of articulation (2. l. a.). Its shorter slits and greater concave side face the anterior side of the leg (figs. 14, 45). Organ No. 13 found on the posterior surface of the metatarsus covers most of the space at the extreme distal end. The slits are transverse to the axis of the leg and they extend around about 120 degrees of the joint. The border is entirely absent. The shorter slits lie on the edge of the dorsal surface (figs. 14, 10).

The organs on the palps have a disposition similar to those of the legs. Their shape is also similar but the number of their slits is less. Organ No. 1 has only two slits instead of three (figs. 13, 27). No. 2 lying on the ventral surface of the trochanter has only seven slits as compared with 15 to 18 found in the same organ on the legs (figs. 13, 26). No. 3 is absent. No. 4 on the dorsal surface of the trochanter has seven or eight slits and its shape is very similar to that of No. 2 (fig. 14). Nos. 5 and 6 have seven slits instead of eleven as on the legs (figs. 13, 14, 38). No. 7 is missing. The shape of No. 8 is more like that of No. 7 of the legs, but its arrangement of slits and disposition correspond to that of No. 8 of the legs. It has only ten slits while on the legs there are twenty-one (figs. 13, 23). No. 9 has the same number of slits as has that organ on the legs, and it is as large as the same structure found on the second and third pairs of legs, it never has any isolated slits (figs. 14, 17). All the other organs on the palps are absent.

On the anterior and on the ventral extreme distal surfaces of the metatarsus of each leg, there is a single large slit. It may or may not touch the line of articulation and its long axis is not quite parallel with the axis of the leg (figs. 13a, 14b, 31). On each the anterior and dorsal surface of all the legs and palps there is a transverse single slit near the distal end of the tarsus (figs. 13c, 14d, 32a, b, c). On the

ventral surface of the palps and legs single isolated slits occur only on the sixth joint of the left palp (figs. 13*e*, 34*a*); on the femur of the first and second legs (figs. 13*m*, 37*a*), and on the tibia of the third leg (fig. 14). On the dorsal surface of both the palps and legs the single slits are much more numerous and are arranged more or less in regular rows. Thus we see several on the sixth and fifth joints of the palps (figs. 14*l*, 34*b*). On the legs they occur as follows—a row on each femur (figs. 13, 14*n*, 37*b*); three or four irregularly scattered on the patella of the third and fourth legs (fig. 13); on the tibia of the first, second and fourth legs a row (figs. 13, 14*f*, 34*c*); only two on each of the metatarsi of the first, third and fourth legs (figs. 13, 14). Most all of these are parallel with the axis of the leg. On either the dorsal or anterior surface of the trochanter of the second, third and sometimes the fourth leg, there are two or more isolated single slits (fig. 14).

Organs No. 14 and 15 lie on the outer edge of the ventral side at the distal end of the chelicera. They are always paired and form a right angle with each other (fig. 13). Organ No. 14 (fig. 51*a*) is the larger and lies near the outer edge. Each organ has four slits, each of which has its own border. All of these borders are more or less connected with each other. Likewise organs No. 16 and 17 are paired, but are located on the outer edge of the dorsal surface at the distal end of the chelicera (fig. 14). No. 16, the larger (fig. 55*a*), lies the nearer the outer edge. It always has an associated single slit (fig. 55*c*). Each organ has six slits whose borders are similar to those of Nos. 14 and 15. On both the dorsal and ventral surfaces of the chelicera several small isolated slits lie along the outer edges (figs. 13*g*, 14, 50).

Organ No. 18 is one of the paired structures found on the dorsal surface of the pedicle near the distal end. Each organ lies near the outer edge and has transverse slits, but the longer axis of the organ lies almost parallel with the axis of the pedicle. The diameter of the slits is very great and each slit has its own border, but all these borders are joined at their sides while the ends are free and do not pass around the ends of the slits as usual, but connect with these ends (figs. 13, 41).

Several scattered slits lie near the outer edges of the maxillæ (figs. 13*h*, 39). Thirty-eight isolated slits of irregular sizes are found on the sternum arranged in a V-shaped figure with the apex of the V at the distal end of the sternal plate. Each row, which is composed of three or four groups more or less irregularly arranged and which

contains about one-half the total sternal slits, is midway between the median line of the sternal plate and the outer edge of the sternum (fig. 13). In the group of five slits (figs. 13*i*, 42) no two are of the same size or shape. The first and third largest ones do not have any distinct dilatation, while the other three do. The second largest slit besides having its border also has a much darker colored circular disc which lies across the border at its middle.

On the ventral surface of the abdomen, we find a large isolated slit on either side of the epigynum near the lower end of the lung-book (figs. 13*j*, 44*a*). Lower down at the same distance from the edge of the abdomen midway between the epigynum and spinnerets, there is another pair of large isolated slits. Just in front of the spiracle there is another pair slightly smaller than the two preceding pairs (fig. 13). On the left spinneret of the first pair there are three small isolated slits (figs. 13*k*, 44*b*).

At the right posterior side of the cephalothoracic shield just above where the right fourth leg is attached there are two minute indistinct isolated slits (fig. 14).

The lyriform organs found in the seventeen day (just hatched) spiderling of *Th. tepidariorum* have the same disposition as the corresponding ones in the adults. But there are none on the first joint of the palps, the spinnerets, maxillæ, labium, sternum, cephalothoracic shield and near the epigynum. In other places the isolated slits are very scarce. As compared with the organs of the adult female, those of the spiderling have almost proportionately the same size, but since the number of slits in the latter is about one-half that of the former, the slits are proportionately larger. In order to compare the number of slits in each organ of the spiderling with that of the adult female, I shall indicate the number of each organ with a Roman letter and the number of slits in it with an Arabic figure. In each case the number of adult slits appears first and of the juvenile second.

Palps.—I 2-0; II 7-5; III 0-0; IV 7-5; V and VI 7-2 each; VII 0-0; VIII 10-4, but the latter does not have the same shape as former; IX 7-4; all others are absent as in the adult, but the large slits on both palps and legs marked *a*, *b*, *c*, and *d* are present as in the female.

Legs.—I 3-2; II 15-5, but the latter are all long and of equal length; III 7-9; IV 14-5, latter are all long and of equal length; V and VI 11-4 each, latter four all long and of equal length; VII 17-8; VIII 21-10; IX 6-3, in latter no isolated slits ever accompany organ as in the former; X 6-2; XI 11-6, in latter slits are about same length and

are all long; XII 9-2, latter two are long ones; XIII 17-12; XIV 8-4; XV and XVI 4-2 each; XVII 6-2, young as adult with an associated slit; XVIII 6-2. By referring to the table (p. 389) we see that while the adult female has 60 compound organs, its young just hatched has only 38. By counting all the slits enumerated above the adult has a few more than twice as many as the young, then by including the isolated slits in both we see as far as number is concerned, that when the young are hatched the lyriform organs are hardly one-half developed. Thus after hatching the slits in the organs more than double themselves; organ No. 1 on the palps, the diffused organ No. 3 on the legs and the majority of the isolated slits make their appearance.

(b) *Other Species.*

In order to ascertain most of the variations found in the other species, reference is made to the tables on pp. 386-393. At the top of this table the families are arranged as Simon recognizes them. Just below the family names are entered the subfamilies, the generic and specific names. The following abbreviations are employed: H, hunters; S, snarers; T, tube-dwellers; the numbers 1 to 7 for the joints of the legs correspond to coxa, trochanter, femur, patella, tibia, metatarsus, and tarsus. Spinn., spinnerets; Chel., chelicera; Max., maxilla; Lab., labium; Stern., sternum; Ped., pedicle; Ceph. S., cephalothoracic shield and Near Epig., includes all the organs on the ventral side of the abdomen, usually occurring near the epigynum; C. O. and S. O., compound and simple organs, and S. S., single slits. Where only one segment is present in the spinnerets I have considered it the first one, although it may correspond to the second or third in other cases. All the specimens were adults. The young of *Th. tepidariorum* is entered only for comparison, but has not been considered in the range or in the comparison of the adults. The total includes all the organs and slits which could be found on all the legs, palp, spinnerets, cheliceron, and maxilla on one side of each specimen. Hence the total contains slightly more than one-half the number for each individual. For the number of organs the amount of error is probably not greater than two per cent., while for the single slits not more than ten per cent. The latter possibility of error is largely due to the three following reasons: (1) the slits when placed in profile are never discernible; (2) on account of the transparency; (3) the caustic potash treatment often causes artificial slits and no doubt often destroys some of those present.

Spinn.	4th Leg.	3d Leg.	2d Leg.	1st Leg.	Palp.	Appendage.	Joint.		Pholcidæ.		Theridiidæ.	
							1	2	c.o.	Uroctea sp. Duf.	s. o.	Urocteidae.
Chel.....							1	2	2	1	1	
Max.....							3	2	2	2	2	
Lab.....							22	6	3	2	1	
Stern.....							55	2	1	12	12	
Ped.....										2	2	
Ceph. S....												1
Near Epigy.												2
Total....	65	5	198	41	12	82	50	5	57	48	6	37
										38	22	22
										22	60	5
										154		

Spinn.	4th Leg.	3d Leg.	2d Leg.	1st Leg.	Palp.	Appendage.	Theridiidæ.			Argiopidæ.								
							Group Theridieæ.			S. Linyphiinæ								
Joint.	<i>tepidari-</i> <i>oran-</i> <i>Koch.</i>	<i>s.o.</i>	<i>porteri</i> <i>Banks.</i>	<i>s.o.</i>	<i>Kentuck-</i> <i>yense</i> <i>Keys.</i>	<i>s.o.</i>	<i>Grammonota</i> <i>inornata</i> <i>Emert.</i>	<i>s.o.</i>	<i>Erigone</i> <i>internalis</i> <i>Keys.</i>	<i>s.o.</i>	<i>Phanetta</i> <i>subterranea</i> <i>Emert.</i>							
1	2	2	2	2	2	2	1	1	2	1	1							
2	2	2	2	2	2	2	1	1	2	1	1							
3	2	2	2	2	2	2	1	1	2	1	1							
4	3	3	2	2	2	2	1	1	2	1	1							
5	3	3	3	2	2	2	1	1	2	1	1							
6	1	10	9	10	10	10	1	1	2	1	1							
7	5	5	5	5	5	5	1	1	2	1	1							
8	1	1	1	1	1	1	1	1	2	1	1							
9	1	1	1	1	1	1	1	1	2	1	1							
10	1	1	1	1	1	1	1	1	2	1	1							
11	1	1	1	1	1	1	1	1	2	1	1							
12	1	1	1	1	1	1	1	1	2	1	1							
13	1	1	1	1	1	1	1	1	2	1	1							
14	1	1	1	1	1	1	1	1	2	1	1							
15	1	1	1	1	1	1	1	1	2	1	1							
16	1	1	1	1	1	1	1	1	2	1	1							
17	1	1	1	1	1	1	1	1	2	1	1							
18	1	1	1	1	1	1	1	1	2	1	1							
19	1	1	1	1	1	1	1	1	2	1	1							
20	1	1	1	1	1	1	1	1	2	1	1							
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99	1	1	1	1	1	1	1	1	2	1	1							
100	1	1	1	1	1	1	1	1	2	1	1							
Total...	59	6	202	58	1	115	59	4	135	48	13	109	52	6	108	42	8	51

Spinn.	4th Leg.	3d Leg.	2d Leg.	1st Leg.	Palp.	Appendage.	Joint.						Range.					
							1	2	3	4	5	6	1	2	3	4	5	6
Chel.																		
Max.																		
Lab.																		
Stern.																		
Ped.																		
Ceph. S.																		
Near Epig.																		
Total...	63	1	64	57	2	43	61	3	42	51	7	66	50	9	64			

The following are those variations which could not be placed in the table. (1) Organ No. 1 on the coxa of the legs in *Moggridgea* and a few others have six or seven slits (fig. 35). (2) On the trochanter of the palps in one-half the cases where two or three organs are present at least one is always and sometimes two are diffused. (3) Concerning the same joint of the first leg, there are 18 species with one diffused organ, 10 species with two diffused organs; for the second leg 23 species each with one diffused organ, 7 species each with two such organs; for the third leg one diffused structure in each of 17 species and 5 species each with two such organs; for the fourth leg in each of 14 species one such organ, while each of 9 species has two diffused organs. On the legs a diffused organ never occurs unless at least two organs are present, and two diffused organs are never seen unless at least three in all are observed. (4) In all species with a low total number of organs, No. 5 and 6 on the femur never have many more than three slits. (5) The paired organs No. 7 and 8 are always present, while in six species No. 9 is absent on the first and third legs; it is missing, however, in only three species on the second and fourth legs. In *Hermacha* this organ on each leg is slightly diffused. No. 7 and 8 in *Caponia* and *Palpimanus* are out of their ordinary position. (6) On the fifth joint of the palp of the first five named species, there is a transverse organ (fig. 40) in the same position as No. 13 on the metatarsus of the legs. In the first four species three or four longitudinal organs occur besides this transverse organ. All of these organs are proportionately large as represented by those of *Moggridgea* (figs. 25, 40, 48, 56). The largest of these (fig. 56) has thirty slits, the greatest number found in any organ of any species. Fig. 12 shows the large organ on the dorsal side of the tibia of *Uroctea*. The other three on this joint are very small. (7) On the sixth joint of the palps the large transverse slits called *c* and *d* were observed in only a few of the species. (8) On the legs the majority of the species have at least one of the two large slits called *a* and *b*. In several cases one of these slits becomes a simple organ and in a few cases as in *Evagrus* or *Atypus* one has changed into a compound organ, while the other one remains a simple organ. Hence, on the sixth joint in the first leg of *Atypus* and on the fourth leg of *Evagrus* there are two compound and one simple organ. As usual one of the former is transverse and the other two are longitudinal. (9) Among the 39 species only *Hypochnilus* has organs on the tarsi. These are small transverse organs located at the extreme distal end always on the anterior side (fig. 49). In almost every species there is at least

one, but in most cases two transverse single slits like *c* and *d*. Besides these in many species there are several other smaller transverse slits. These usually lie near the larger ones but not so near the distal end. (10) Fig. 29 shows three slits and three hairs found on the first joint of the spinnerets of *Evagrus*. Organs on the spinnerets occur in only five species. In *Hytiotes* there is a small transverse compound organ at the base of the spinnerets; at the same place in the male of *Troglhyphantes* and *Epeira* this organ is transverse and simple (fig. 19). On the ventral extreme distal end of the first joint of *Mimetus* there is a transverse organ of nine slits; at the same location on the foremost spinneret of *Tama* there is a large transverse organ with eleven slits (fig. 33). (11) For the chelicera, fig. 28 shows two of the four simple organs found in *Dictyna*. Here the border is entirely absent. In *Hyptiotes* (fig. 20) the border surrounds all the slits of each organ. Fig. 11 shows the very large organ in *Moggridgea*. (12) Fig. 21 represents two of the thirteen slits on the labium of *Ariadna*. (13) Whenever the number of slits on the sternum is approximately 24, they are arranged in groups of threes. In such cases the proximal end of each coxa faces one of these eight groups. Whenever the number is much smaller than 24, they are not arranged in groups, but are scattered irregularly. Whenever the number is much more than 24, then they are grouped as in *Th. tepidariorum*. (14) Fig. 36 shows two of the twenty very small slits on the pedicle of *Moggridgea*. (15) When the minute slits can be detected on the cephalothoracic shield they occur usually at either side or directly in front of the pedicle. Fig. 46 shows three taken from *Ariadna*. (16) Near the epigynum we have the following: Fig. 22 shows two of the twelve scattered slits in the female of *Pholcus*. These twelve are found on both sides of the epigynum a little above the ones marked *j* in *Th. tepidariorum*. Fig. 54 shows a group of these in *Moggridgea*. They are drawn much too close together. Fig. 43 represents the two diffused organs in front of the epigynum of *Calculus*, while fig. 47 shows one of the two organs in front of the epigynum of *Dysdera*. In only a few cases have the two pairs of large slits been found which lie between the epigynum and spinnerets as shown in *Th. tepidariorum*.

(c) *Individual and Sexual Variations.*

For a study of the individual variation, I have used the fourth pair of legs of ten males and ten females of *Th. tepidariorum*, thus making forty legs in all. Organ No. 1 in the females occurs nine times to

only six in the males on the right side; on the left side ten times in the females to nine times in the males. Organ No. 3 of the females on both sides is much oftener diffused than is that of the males. The only other striking difference is the greater number of isolated slits on both legs of the females. In two cases in the males a simple organ takes the place of a compound one, and in the legs on either side in both sexes an organ is occasionally absent. In all other cases in which I have carefully examined more than one specimen of the same species, I have not found any individual variations of more importance than the above. Hence we see that the organs are pretty constant on both sides of the body in both sexes, while the number of single slits varies considerably both individually and sexually.

By carefully comparing the males and females of the same species we see that there are no variations except what can be considered as individual variations. The only difference worth mentioning is the great number of single slits on the last joint of the palps in the males (fig. 9), while none or only a few are found at the same place in the females. By referring to the totals in the table one sees that the males of *Th. tepidariorum* and *Phidippus* have one compound organ less than the females; the male of *Pholcus* two less; the male of *Troglohyphantes* three less; an equal number in both sexes of *Linyphia*; the male of *Lycosa lepida* one more, and the male of *Agalena* three more organs than the female.

(d) *Conclusions.*

Now, to interpret the meaning of the totals in the table, it is evident that relationships play no part at all, for there is a great range of variation within a genus or family. Therefore these organs are not useful for taxonomy. As already stated individual and sexual variations are very slight. Specific variations are also very slight as seen in the two Lycosas, and in the three species of *Theridium*. Generic differences are not very great when the various genera have a similar habitat, as in *Mogridgea*, *Hermacha*, and *Evagrus*; a less variation between *Tetragnatha* and *Epiera*, but the same number of organs in *Dysdera* and *Ariadna*; however when the habitat is dark and damp the number of compound organs is usually much less as shown in the linyphiid cave forms and in a linyphiid littoral form, *Grammonota*. The most important variation in the morphology of the lyriform organs can certainly be correlated with the method of capturing food. In the manner of securing food, spiders are divided into three classes as follows: (1) The hunters are those which wander about in search of

food and when sufficiently close they jump and seize the prey. They use no snares whatever in capturing food. (2) The snarers catch their food with snares and never hunt for it. (3) The tube-dwellers run to the entrance of their tubes in order to catch the prey. These three classes in the table (pages 386-393) are referred to as H, S, and T. The hunters without exception have more compound organs than either the snarers or tube-dwellers. The average number of compound and simple organs and single slits for the hunters is 61-3-100; for the epigæan snarers 58-4-99, and for the littoral and cavernicolus snarers 51-6-119; but for snarers of all kinds 56-4-105; for the tube-dwellers 49-5-144. Hence the number of single slits in both hunters and snarers is the same while the number of organs varies considerably. The cave forms have a few more single slits than either the hunters or epigæan snarers, but their number of organs is much reduced. The tube-dwellers have the greatest number of single slits, but the fewest organs of all. The range for the hunters is 69-51 c. o., 7-0 s. o., 375-34 s. s.; for the epigæan snarers 66-49 c. o., 11-0 s. o., 241-18 s. s.; for the other snarers 59-42 c. o., 13-1 s. o., 217-51 s. s., but for both kinds of snarers 66-42 c. o., 13-0 s. o., 241-18 s. s. and for the tube-dwellers 50-48 c. o., 6-3 s. o., 237-60 s. s. The difference between the maximum and minimum is practically the same between the hunters, epigæan and cavernicolus snarers but when all the snarers are compared with the hunters, the former vary much among themselves. The reason why there is such a slight range among the tube-dwellers is perhaps because *Caponia*, *Ariadna* and *Dysdera* are the only forms included here.²

All true cave spiders are snarers and it is manifest that the more they have become adapted to a subterranean life, the more their lyriform organs have degenerated. Thus to arrange them according to the degree of such an adaptability, we have the following series with regard to the number of compound organs: *Th. kentuckyense* with 59, *Th. porteri* 58, *Erigone* 52, *Troglhyphantes* 50, *Linyphia* 48, and *Phanetta* 42, of which series there is a gradation from the epigæan *Th. tepidariorum* with 60 compound organs which nests in walls and outhouses to *Phanetta* which is able to adapt itself to any place in a

² *Calculus* and *Ammoxenus* have not been included in the above comparison because I have been unable to find any literature concerning their habitats. *Calculus bicolor*, from South Africa, is a new species described by Purcell, and its habits have not been described. Simon (1892) described for the first time and created a new family for *Ammoxenus* from South Africa, but all he says about the habitat is—"Ils se trouvent à terre, dans les endroits découverts, et ils courrent au soleil avec une telle rapidité qu'il est difficile de s'en saisir."

cave where the three following necessary requirements are present: (1) Total darkness, (2) an even temperature and (3) a saturated atmosphere. In Banta's (1907) cave work and my recent paper (1911) on some cave arachnids, their habitat is briefly discussed. The first three species may be found from twilight localities where food is very abundant and where there is a considerable range in the annual temperature and a daily range in the humidity to places in total darkness where insects are rather scarce, and where there is only a slight range in the temperature and humidity. These first three are much larger in size, all the eyes are present and they are much darker in color than are the last three. The fourth and fifth species are never found in the twilight, but always where the three above necessary requirements occur, although most abundantly where food is comparatively plentiful. The average color is rather light and the eyes are partially or totally absent. *Phanetta* may be found in the same localities as the above two species, but furthermore it is able to live in any part of a cave if the three necessary requisites are present regardless of the distance from the entrance or the paucity of the insect food. Of the six species it is the smallest, lightest in color and perhaps has the greatest percentage of totally blind individuals, although in twenty-seven specimens Banta did not find any totally devoid of eyes. Since *Grammonota* lives under wet eel grass in the dark, its small number of organs probably can be explained in a similar way.

Now, since hunting spiders have the greatest number of lyriform organs, and as these usually contain more slits than those of the snarers or tube-dwellers, we must conclude that the method of capturing food has brought about these changes in the number of organs.

3. Discussion.

(a) Disposition.

Bertkau (1878) was the first to notice some isolated slits grouped together and located at the distal end of the segments in Araneæ. Dahl (1883) first discovered and described the transverse organ No. 13 on the metatarsus. Schimkewitsch (1884) was the first to observe the isolated slits on the sternum but did not recognize them as lyriform organs. The next year (1885) the same author found eleven organs on the legs and four on the palps of *Epeira diademata*, while I have observed fourteen on the legs and six on the palps of *Epeira mirmorea*. Wagner (1888) first saw the two organs on the pedicle and the single slits near the spinnerets, but he did not recognize them

as lyriform organs. Gaubert (1890) described the disposition of the lyriform organs and said that these structures were as characteristic for arachnids as are the pectines for scorpions. He gave them the appellation of "lyriform organs." In (1892) Gaubert worked on several species and found the organs as follows: one on the coxa of the legs and palps; three on the trochanter; two on the femur; three on the patella; three on the tibia; one on the metatarsus; no organs but occasionally isolated slits on the tarsus. He said that the four pairs of legs have similar organs and the first four segments of the palps have organs located like those of the legs. Therefore he was the first to see organ No. 1 on the coxa, and he has seen all the organs present on these appendages, but he failed to observe them elsewhere. Hansen (1893) selected *Epeira diademata* Clerk ♂, the same species that Gaubert used, and searched for organs and slits which were overlooked by the latter observer. Besides finding the thirteen organs on each leg, some isolated slits, the organs on the palps, chelicera and the slits on the sternum as pointed out by Gaubert, Hansen found many isolated slits of various sizes irregularly distributed on the palps, legs, chelicera, maxillæ, labium, near the epigynum, on the spinnerets, and on the cephalothoracic shield in much the same manner that I have described. Thus he was the first to recognize the two organs on the pedicle as lyriform organs and pointed out for the first time the isolated slits near the epigynum, on the spinnerets, labium and cephalothoracic shield.

My more comprehensive study of these structures has enabled me to find all those organs pointed out by my predecessors, besides those compound organs occasionally on the fifth joint of the palp, on the tarsus of the legs and compound and simple organs on the spinnerets and in front of the epigynum.

(b) *Structure.*

Bertkau (1878, 1885) described an enlargement at the middle of the slit covered by a fine membrane and connected with a nerve fibre. Dahl described a vessel under the transverse slits of organ No. 13. Schimkewitsch says a lyriform organ has a chitinous coat which may be incomplete and has edges which separate the parallel slits. He describes the nerve fibres passing to the organ and their connection with the ganglia (sense cells), but he failed to see the union of the latter with the nerve "pédieux." Wagner states that these organs present at the exterior a very thin membrane which afterwards covers the dilatations which are located at the middle of the slit. Gaubert

has described the structure of an organ very nearly as I have, but since his drawing is much too small and fails to give most of the details one cannot gain from it the proper conception of such a structure. He shows only six sense cells, all of which are at the base of the hypodermis just beneath the organ. Also he connects the nerve fibres with the dilatations, but he fails to show how the other end of the sense cells connects with the nerve of the leg.

(c) *Disposition in other Orders of Arachnids.*

In regard to the lyriform organs of other orders of arachnids which have been studied by Gaubert and Hansen, a brief summary is necessary in order to understand the development of these structures throughout the class of Arachnida. Gaubert failed to find any organs in the Scorpions and Solifugids, and he saw only a small portion of the organs present in the Pedipalps, Pseudoscorpions and Phalangids. Hansen who examined more specimens and with greater care, found the following in two species of different genera of the scorpions: several isolated slits on the trochanter and femur of the legs and palps; numerous slits on the patella, tibia, and metatarsus of the legs. All of these vary much in size and are irregularly scattered. Almost all of these slits are parallel with the axis of the leg and the dilatation is always at the proximal end.

In short, Hansen has found the lyriform organs in one family, Thelyphonidae, of the Pedipalps as follows: the legs and palps are abundantly supplied with scattered slits and the only organ which occurs is on the metatarsus and it is highly developed. The chelicera have numerous slits; the cephalothoracic shield and sternum only a few, while the dorsal and ventral sides of the abdomen have many. In another family, Phrynidæ, the legs besides having many slits also have two organs on each trochanter. There are many slits on the chelicera, dorsal and ventral sides of the abdomen and only a few on the cephalothoracic shield.

According to Hansen and Sörensen (1904) lyriform organs are completely wanting in the order Palpigradi.

Among the Solifugids Hansen has found only five scattered slits on the last and fifteen on the first joint of the chelicera. These are very different in size and are irregularly scattered. He says: "Undoubtedly we have here lyriform organs in a somewhat modified shape."

For the Pseudoscorpions Hansen states that only a few isolated slits are found on most of the joints in the legs and palps, while an

organ composed of five slits is found on the second joint of each species. Chelicera and maxillæ with only a few, both ventral and dorsal sides of the abdomen and dorsal side of the cephalothorax with many small scattered slits.

Hansen and Sörensen stated that it was impossible to find lyriform organs in the order Ricinulei.

Concerning the Phalangids Hansen says that numerous isolated slits of unequal lengths occur on the first three joints of the legs, third joint of the palps, chelicera, ventral side of the abdomen, but only a few on the cephalothorax and dorsal side of abdomen.

Gaubert was unable to find any lyriform organs in the order of Acarina. Hansen thought that he found some scattered, very tiny slits on the shield and a most remarkable transverse slit on the legs of one species. Thus he thinks that they appear as single slits in this family.

To briefly summarize the discussions about the disposition of the lyriform organs in all the orders of arachnids, we see that scorpions possess many irregularly scattered slits of various sizes on the legs and palps, but no compound organs. For the family, *Thelyphonidæ*, of the pedipalps there are many scattered slits on all the appendages, a few on both sides of the cephalothorax, while many are scattered all over the abdomen. In this family there is only one compound organ on each leg, while in the family, *Phrynidæ*, there are two compound organs on each leg besides the many slits. For the solifugids the only signs of lyriform organs are a few scattered slits on the chelicera. The pseudoscorpions have only one organ of five slits on each leg and scattered slits occur everywhere. The phalangids have only numerous slits scattered everywhere; the acarinids have nothing more than a few scattered slits, and no slits have ever been found in the *Palpigradi* and *Ricinulei*.

(d) *Phylogeny.*

Thus it is clear that the development of the lyriform organs in all the orders except *Araneæ* is in a very primitive state. In the degree of development perhaps the pedipalps stand next to the araneads for some of them have two compound organs on each leg, while *Palpigradi* and *Ricinulei* have these structures totally absent. It seems probable that at one time all kinds of lyriform organs were nothing more than minute slits irregularly scattered over all parts of the entire body as seen in some of the lower orders. Then when organs made their appearance the tiny slits on the dorsal side of the body dis-

appeared as illustrated in the pedipalps. This is further exemplified with the araneads in which one never finds isolated slits on the dorsal side of the abdomen and none on the dorsal side of the cephalothorax except a few that still persist on the cephalothoracic shield. In some species among the araneads the single slits seem to be as numerous as ever, but in all cases they have become more or less regularly distributed. Where the single slits are as numerous as ever, then the compound and simple organs must be entirely new formations.

Among the lower orders the range is from a total absence of either isolated slits or organs for the entire animal to many single slits plus two compound organs for each leg. Among the araneæ the range is from 41 c. o., 12 s. o., 82 s. s. to 69 c. o., 2 s. o., 64 s. s. The total number of slits in all these organs plus the scattered ones of the latter aranead is probably twice that of the former. According to this the development of the lyriform organs in the latter is twice that of the former, while in the lower orders this ratio is doubled many times.

II. PHYSIOLOGY.

4. Experiments.

(a) Olfactory Sense.

Triangular experimental cases were constructed by using three pieces of glass, two of which were 10 cm. wide by 13 cm. long and the other 6 cm. wide by 10 cm. long. Cheese cloth served as a bottom. The glass and cheese cloth were held together with adhesive tape. A top of cardboard was laid over each case to prevent the escape of the specimen. Cases of the same dimensions except height were used for the attiids. These were only one centimetre high with a glass top. The extreme ends of the experimental cases rested on two supports which were placed on sawdust, the latter being used to break the jar caused by heavy walking. A screen was placed in front of the cases to prevent the spiders from seeing the observer.

On account of their size, abundance, and because their webs did not interfere with the experiments *Lycosa lepida*, *L. scutulata*, and *Phidippus purpuratus* were employed. However in one test *Pardosa lapidicina* Emert. was used. In all cases the spiders were brought immediately fresh from the fields, then and each day afterwards they were fed and watered. They were experimented with in series of fourteen in which each specimen was tested each day with five or six different odors for four or five days. The first experiments were made with the following five oils; clove, thyme, wintergreen, peppermint and bergamot, each of which was kept securely in a small vial. The

spiders were left undisturbed in the cases over night. The next morning if they were perfectly quiet a vial of oil was placed directly beneath and within one centimetre of each individual. Time was counted in seconds. An intermission of forty-five minutes elapsed between any two tests of various odors. The following are the average results of the tests for four or five days with the above five oils.

Clove.—Most specimens moved away slowly; a few moved away quickly; some moved only slightly; several worked palps, chelicera and legs; one rubbed palps and two threw up front legs quickly. Time ranged from 3 to 90 sec. with an average of 27 sec. for *L. lepida*; for *Phidippus* from 3 to 32 sec. with an average of 13 sec. Forty-one specimens were used.

Thyme.—Almost one-half moved away slowly; the same number away quickly; the remainder either raised up quickly, threw up front legs, worked palps and chelicera or rubbed their legs together. Time for *L. lepida* 2 to 95 sec. with an average of 10 sec.; for *Phidippus* 2 to 15 sec. with an average of 4 sec. Forty-two specimens were used.

Wintergreen.—The majority moved away slowly; several away quickly; several arose quickly; a few worked palps, chelicera and legs; one lay down over the odor, and one rubbed legs together. Time for *L. lepida* 2 to 80 sec. with an average of 11 sec.; for *Phidippus* 3 to 15 sec. with an average of 7 sec. Forty-eight specimens were employed.

Peppermint.—All either moved away quickly or arose quickly and then moved away slowly; some of these after moving away worked palps, chelicera and legs; three threw up front legs; one lifted feet high; one rubbed legs and chelicera together. Time for *L. lepida* 2 to 13 sec. with an average of 6 sec.; for *Phidippus* 2 to 7 sec. with an average of 3 sec. Forty-eight individuals were used.

Bergamot.—The majority moved away slowly; the remainder either raised up quickly or moved away quickly; only a few worked palps, chelicera and legs. Time for *L. lepida* 3 to 45 sec. with an average of 14 sec.; for *Phidippus* 3 to 35 sec. with an average of 6 sec. Forty-one specimens were employed.

The total average of the results for the five oils is 13 seconds for *L. lepida* and for *Phidippus* it is 7 seconds.

Now, since it may be contended that the results obtained by using the above oils are due to an irritation of the skin rather than due to an olfactory sense, I also used the following which cannot be classed as irritants:

Buttercup (Ranunculus sp.).—Both the fresh and decayed flowers were employed, and there was practically no difference either in time

or reactions. The general result was to move away slowly; sometimes a few worked palps and chelicera and one lay down over the odor. In this test only six specimens of *Pardosa* were used with the fresh flowers. Time 23 to 56 sec. with an average of 32 sec. The same number of specimens of *L. lepida* were employed with the decayed flowers. Time 3 to 120 sec. with an average of 36 sec. In this as in other cases 120 seconds was the limit of time without result.

Decayed Snail (Littorina littorea).—Most moved away slowly; only a few away quickly and only a few worked palps, chelicera and legs; one threw up front legs and one rubbed legs together. Time for *L. lepida* 7 to 120 sec. with an average of 61 sec.; for *Phidippus* 5 to 120 sec. with an average of 68 sec. Thirty-four specimens were used.

Squash Bug (Anasa tristis).—One-half moved away slowly, the other half either arose quickly and moved away slowly, or moved away quickly when the squash bug was held in the fingers beneath the spider; a few after moving away worked legs and palps; one lay down over the odor and one followed the odor when the bug was moved beneath the case. Squash bugs which were caused to exhaust all their secretion and had become odorless were placed in the cases with the spiders. In almost every case the spider within a few minutes seized and ate the bugs. When squash bugs with a strong odor were placed in the cases the spiders never came within reaching distance of them and usually remained away from the bugs and when the latter moved toward the spiders, the araneads gave them the right of way. Time for *L. lepida* 3 to 11 sec. with an average of 7 sec.; for *L. scutulata* 3 to 25 sec. with an average of 13 sec.; for *Phidippus* 3 to 6 sec. with an average of 4 sec. Twenty-one specimens were employed.

Phalangids. Most moved away slowly; the others moved away quickly, or moved only slightly; one threw up front legs and two turned around. The phalangids were held in the fingers beneath the cases. Only occasionally when phalangids were put into the cases did the araneads eat them. Time for *L. lepida* 3 to 25 sec. with an average of 8 sec.; for *L. scutulata* 5 to 55 sec. with an average of 19 sec. Thirteen individuals were used.

Thus the general average in time for the five oils was ten seconds, while for the four odors found in nature the time was thirty seconds. Hence, it is evident that spiders respond to other odors besides those from irritating oils, and that they have a true olfactory sense.

To experiment with araneads collected miscellaneous without regard to sex, age, time of moulting, whether parasitised or not, and conditions of the weather, one obtains all kinds of variations and complexities. Not enough males were used to ascertain positively their

degree of sensitiveness to odors, but they seemed to respond slightly quicker than do the females. Perhaps this is due not to the higher development of their olfactory organs, but to their greater activity. Probably the same reason is sufficient to explain the quicker response to odors of *Phidippus* than of the *Lycosas*. Only a few experiments were conducted with spiderlings. In these few cases their actions were not essentially different from those of the adults. Females about ready to oviposit were generally very slow to respond and in a few cases were almost negative to odors. A few hours before and after moulting specimens were entirely negative to odors. On the first day a female of *Trochosa frondicola* (Emert.) responded rather slowly; on the fifth day she was almost negative; on the sixth day a large insect parasite was removed from her abdomen. After this she lived two months but never again responded readily to odors. Other individuals of her kind also responded very slowly. Ten individuals of *Ariadna bicolor* likewise responded very slowly; when not in their tubes their average time was 63 seconds for the five oils, and when in their tubes they rarely responded to any kind of odors. A female of *Dysdera interrita* which did not spin any kind of a nest responded still more slowly; the average time for the five oils was 70 seconds. Generally on damp or rainy days all specimens responded very slowly and since no definite conclusions could be derived by including such data, all results on these days have been eliminated. If the individuals were normal in every way they may be educated to respond to odors more quickly each successive day. In twenty-three specimens of *L. lepida* the time for the first day was 14 seconds, for the second day 12 seconds, thus making an increase of fourteen per cent.

(b) *Hearing.*

In order to determine whether spiders show any response to sounds which a person may hear any day in the same environs in which arachnids live, I placed five male crickets, two small and one large katydid beneath the experimental cases. The pitch of all the cricket chirps were very similar, but the notes of the small katydids were rather high, while those of the large katydid were pretty low. For over a week's time I watched the spiders every day very carefully, but not once did I ever notice a single spider show the least response. I observed very closely the first time the insects were brought into the laboratory, and in order to test them repeatedly the music makers were removed from the room, then were brought back after a short time, but in every case the result was a negative one. Also it was noticed that there was no response whatever whether the araneads were quiet,

or moving when the chirping or singing began. If they were moving when the music began they did not cease, but continued to move as if nothing were happening. Eighteen individuals of *Lycosa* and *Phidippus* were employed.

Therefore if spiders have any auditory sense why do they not respond to the very sounds which a human being can hear at all times immediately in their neighborhood? If quiescence can be considered as a sign of hearing why did not these spiders stop moving when the crickets began to chirp or when the katydids began to sing? Furthermore large spiders can easily catch crickets and small katydids, but as yet there are no observations which show that the sense of hearing aids araneids in capturing their prey. One day I saw a *L. scutulata* and a small katydid on the same weed. The insect sang continuously, I watched the spider carefully for several minutes, however it did not show the least sign of hearing the katydid as far as I could observe.

(c) *Function of the Lyriform Organs.*

In order to ascertain whether the olfactory organs are localized in the palps or in the maxillæ, the former were first removed from eleven specimens of *Phidippus*. The operation was performed by seizing the coxa of the palps with a small pair of forceps, then by giving a quick jerk the appendage was detached, thus leaving only a very small opening through which a minute drop of blood emerged. To cut the appendages off caused the specimens to lose too much blood which in many cases was fatal. The maxillæ of the same eleven were removed in the same way the second day after the removal of the palps. These spiders were the only ones found which were able to endure a double operation of this kind, but after such an operation they did not hesitate to catch and eat flies as usual. The following table gives the results of the average time in seconds for the five oils before removal of palps, after removal of palps and after removal of palps and maxillæ both.

No. of specimen.	Before removal of palps (in seconds).	After removal of palps (in seconds).	After removal of palps and maxillæ (in seconds).
77.....	3	4	4
75.....	7	8	7
97.....	5	5	4
98.....	3	5	14
99.....	4	5	6
106.....	4	4	4
108.....	7	7	7
123.....	7	7	7
129.....	3	3	4
130.....	6	4	4
131.....	4	5	5
Average.....	5.0	5.2	6.0

Thus it is seen that before any operation the average time is five seconds, after removal of palps 5.2 seconds, with palps and maxillæ both removed it is 6 seconds. Therefore after considering the 14 per cent. increase of response on the second day, it is evident that the palps have but little to do with the olfactory sense. Moreover the maxillæ seem to play a slightly more important rôle but this may probably be due to the effect of the operation, because the spiders were slightly less active after the removal of the maxillæ.

Judging from the structure of the lyriform organs, we must conclude that they have some kind of a sensory function. Sight, touch, taste and hearing may be eliminated at once for the following reasons. The eyes serve for the sense of sight. Spiders are no more tactile near or directly on these organs than elsewhere. The taste organs would have to be associated with the mouth. Since it is evident that spiders cannot hear, then these organs could not have an auditory function. Now, there are left for consideration the humidity, olfactory and temperature senses. No experiments were performed to determine the humidity sense, but in my opinion spiders do not have such a sense.

In order to ascertain whether the lyriform organs have an olfactory sense fifteen large adult *Lycosa lepida*, fresh from the fields and all normal in every way, were selected for the varnishing operations. Here as in other cases each spider was fed and watered each day. These fifteen Lycosas were tested carefully with the five oils to see if they had the correct olfactory perception. Late in the afternoon all the lyriform organs (single slits not included) on the legs, palps, chelicera, mouth parts and sternum were carefully varnished with yellow commercial vaseline by placing a tiny daub of this substance on each organ. Great precaution was taken not to use too much vaseline and not to get any of it on the lung-books. Immediately after being varnished the spiders began to clean themselves and removed practically all the vaseline from the chelicera, mouth parts and tarsi of the legs and palps. After one day's time the remaining vaseline did not spread very much, but after four or five days it formed a thin coating over all the legs, cephalothorax and sometimes over the abdomen. When the vaseline covered the lung-books and tracheæ the spiders died in a short time. Most of these araneads, however, lived at least four or five days after such an operation, while some lived fifteen to twenty days, and a few survived almost the entire summer. In these latter the vaseline had all evaporated and the arachnids again responded normally to odors. After the operation the spiders

took water and food in the normal way and then they were left undisturbed during the night. The next morning they were tested again with the five oils. The following table gives the average in seconds for the five oils before and after being varnished.

No. of specimen.	Before varnishing (in seconds).	Next morning after varnishing (in seconds).
♀ 37.....	4	57
♂ 46.....	3	54
♀ 51.....	9	77
♀ 52.....	6	51
♀ 61.....	5	78
♂ 75.....	3	82
♀ 81.....	11	64
♀ 90.....	4	32
♀ 93.....	4	39
♀ 94.....	8	97
♀ 96.....	6	33
♀ 116.....	8	50
♀ 117.....	15	74
♀ 118.....	8	82
♀ 119.....	6	41
Average.....		7.0
		61.0

Hence, the above table shows that the average for all the spiders before varnishing was 7 seconds and after the operation 61 seconds, thus increasing the time nine times. The thin coating of vaseline on the lyriform organs affected No. 117 the least. It responded only five times slower. No. 75 was affected the most. Its time was increased twenty-seven times. Some of these specimens were tested the second, third and ninth day after being varnished. The result was a gradual decrease in time. At the fourteenth day the varnished spiders had almost returned to their normal state for detecting odors.

Now, since this yellow vaseline itself has a slight odor, three sets of controls were used to determine whether the vaseline odor interfered with the response to other odors. First, vaseline in little paper boxes was suspended in the cases and left over night. The cases were made as near air-tight as possible, so that the next morning the air inside the cases was thoroughly permeated with the vaseline odor. Tests with the oils were now prosecuted with the vaseline still suspended. Second, a lump of vaseline was placed on the floor of the cases. The spiders paid no attention to and ran over it as if it were a pebble. Third, a daub of vaseline was placed on the dorsal surface of the cephalothorax and abdomen where it could not interfere with any of the lyriform organs, and where the araneads could not rub it off. Thus it was ascertained that the vaseline odor did not interfere with the

response to other odors, because the time in seconds for each test was exactly the same after as before using the control.

In view of the above facts we are safe in assuming that the lyriform organs function in some measure as olfactory sense organs.

(1) *The Temperature Sense.*—As Gaubert (1892) came to the conclusion that the lyriform organs are an apparatus to determine temperature and perhaps other general senses, a set of experiments was performed in order to test his statement.

A temperature case was constructed by making a glass case 40 cm. long, 5 cm. wide and 10 cm. high with a cheese cloth bottom. At one end placed at right angles was suspended a tin box 20 cm. long, 10 cm. wide by 3 cm. high, so that only 5 centimeters of one end of this box were under the glass case. At the other extreme end of the tin box was placed a small alcohol lamp to heat the water in this box. A piece of glass served as a cover for the box, the top of which was just one centimeter beneath the bottom of the temperature case. One thermometer was laid horizontally on the floor of the temperature case with the bulb over the water. A second thermometer was placed vertically in the other end of the temperature case as a control. Its reading always coincided with that of the normal temperature of the room. Both thermometers had previously been tested.

Ten specimens of *Lycosa lepida*, one at a time, were left in the temperature case for several hours until they came to perfect rest over the water in the tin box and near the bulb of the thermometer. Now the water was gradually and gently heated. Before varnishing the lyriform organs the spiders moved away from the heated region when the temperature on an average was raised 11.2° C. After varnishing the same specimens moved away when the temperature on an average was raised 12.75° C. Since more specimens of *Lycosa lepida* could not be found, ten *L. scutulata*, a very similar form, were used in the same way. Before being varnished they moved away from the heated end when the temperature on an average was raised 15.5° C.; after being varnished on an average of 14.2° C. In each test the time was approximately 15 minutes and each specimen was tested with odors after being varnished to see if the varnishing had been well done. Thus before being varnished twenty specimens of *Lycosa* left the heated end of the temperature case when the temperature was raised 13.3° C. and after being varnished they left that end when the temperature was raised 13.4° C. It hardly seems probable, therefore, that the lyriform organs are an apparatus to determine temperature as Gaubert thought.

In all the experiments of various kinds 173 individuals have been used. In conclusion the evidence favors the view that the lyriform organs function only as olfactory organs.

5. Discussion.

(a) *Function of the Lyriform Organs.*

Bertkau (1878) supposed that they have an auditory sense. Dahl (1883) thought that organ No. 13 on the metatarsus was an apparatus to help in the spinning; since the same organ is found in other members of the arachnid group which do not spin, this hypothesis is no longer admissible. Vogt and Yung (1894) suggest that these organs have a respiratory function. They made this statement based upon a supposed vessel placed below the organ as described by Dahl. Since this vessel never existed their suggestion can have no force. Schimkewitsch (1885) attributes an auditory rôle to them, and thinks that they play the same part as do the "chordotonaes" of Graber which are found in adult insects and their larvæ. This function is not yet sufficiently demonstrated in insects. Wagner has the same opinion as Bertkau and Schimkewitsch, but since none of these preceding observers have performed any experiments to prove their views we need not further consider their hypotheses.

Gaubert concludes that the lyriform organs are an apparatus for perceiving heat and probably the sense of humidity and senses in general. He varnished (but does not say with what kind of varnish) the lyriform organs of several *Lycosas* carefully so that no more of the surface was covered than necessary and so that the varnish did not interfere with the articulations. These specimens and several which had not been varnished were placed in a large glass vessel. In one end of this vessel he placed a shelter or protection and, when the spiders had come to rest, the other end of the vessel was lowered into hot water. He says: "Quand la température commence à s'élever les Araignées n'ayant subi aucune préparation abandonnent leur retraite et se dirigent vers l'autre partie du bocal, celles qui ont les organes lyriformes vernis ne cherchent à fuir qu' *on moment* après, lorsque la température est plus élevée."

(b) *Olfactory Experiments.*

Robineau-Desvoidy (1842), according to Packard (1887), said that the olfactory sense of spiders is very well developed and localized in the mandibles.

Dahl (1884) found a very peculiar sense organ in the maxillæ of spiders. He called it an olfactory organ because he failed to find any olfactory structure near the breathing apparatus and because its location is not suitable for any other function. He performed no experiments to determine its office. According to my experiments it has probably not the slightest olfactory sense. He experimented on various species with turpentine and clove oils, but was not able to ascertain whether they have the power to distinguish differences in various oils. Each oil repelled the specimens in a like manner.

Dahl (1885) states that Bertkau does not agree with him in regard to the histology of his so-called olfactory organ.

The Peckhams (1887) experimented on various species with strong smelling oils and perfumes. Three species, *Epeira hortorum*, *Dolomedes tenebrosus* and *Herpyllus ecclesiasticus* did not respond to the test. Sometimes the legs were rubbed between the palps and falces. Various other movements also were exhibited similar to those I have described. Among spiders of the same species there was a great degree of difference in the sensitiveness to various odors.

McCook (1890) concludes from experiments and observations that spiders have little sense of smell, although they are in some way affected by certain odors. At first he entertained the opinion that the sense of smell in spiders, like that of hearing, abides entirely in the delicate hairs covering the creature. Later, judging from the experiments of the Peckhams, he states that their experiments would indicate that the olfactory organs are distributed more or less over the entire surface of the body, especially at the tips of the feet and at the apex of the abdomen. After the extirpation of the palps of two females, there was no apparent loss of sensitiveness.

Pritchett (1904) states that both kinds of odors, non-irritant and irritant, repel both males and females in the same degree. Individuals with either palps, or first pair of legs, or tarsi of all legs removed, responded normally when all the other appendages were intact. Also they responded in the same way when the sense hairs were removed from all the legs.

(c) *Sense of Hearing.*

Boys (1880) asserted that the garden spider responded readily to the vibrations of tuning forks, but since this is an orb-weaver the web certainly must have been irritated in some way to cause the so-called auditory reactions.

The Peckhams found that only web-makers responded to tuning

forks, while those that make no webs gave not the slightest heed to sounds. They attempted to explain this phenomenon by the difference in the method of capturing food, but now it is pretty generally agreed that in all such experiments the vibrations from the tuning forks agitate the webs.

McCook cites several recorded cases where spiders are supposed to hear and in a few cases to really enjoy music, but he thought that such responses of the araneads could be explained in other ways than by imagining that they have an auditory perception. McCook concluded after many experiments with musical instruments, various sounds of the human voice and sonorous objects that if spiders have any sense of hearing, that sense is distributed, like the sense of smell, over the entire body and that it can scarcely be distinguished from the sense of touch.

Dahl (1883) called certain peculiar hairs on the three end joints of the legs auditory hairs. They are even so constant in arrangement that he attaches an important taxonomic significance to them. In order to prove the possibility that they have an auditory function he placed the foot of a dead dried spider under the microscope. Then he struck a deep tone on a violin and noticed a vibration of these hairs. From this evidence he claimed that spiders have an auditory sense, although with live araneads he could not always notice any reaction to tones. He stated that a nerve fibre runs out from the base of each of these hairs but presents no drawing of such. The next year Dahl described and presented a drawing of the nerve of a spider's leg which can be easily recognized by its long irregularly arranged nuclei. He said that from this nerve fibres run out to the individual auditory hairs, but even here he produces no drawing of such a connection. Judging from the similarity in structure of various kinds of hairs Wagner (1888) asserted that Dahl's so-called auditory hair could not have such a function.

Westring (1843) was the first to mention a stridulating organ in a theridiid, *Asagena phalerata*. Wood-Mason (1875) exhibited specimens of a gigantic theraphosid which he called *Mygale stridulans*. These produced loud stridulating sounds. Campbell (1881) observed these organs in three or four different species of theridiids. Peal (1895) noticed the stridulating phenomena of an Australian spider. Pocock (1895) discovered and gave drawings of a stridulating organ in the male of *Cambridgea antipodiana*, an agelenid. Since the organs were present only in the males he concluded that the sound emitted must be a sexual call. Spencer (1895) observed a theraphosid which was

able to produce a stridulating sound. Montgomery (1909) stated also that the genus *Geotrecha*, a drassid, exhibits a good case of stridulation. In the theridiids and *Geotrecha* as yet the stridulation has never been heard by the human ear. It cannot be a sexual call for the sexes in *Geotrecha* show no responses whatever to the stridulation of each other and do not even stridulate during the mating. Even if the sound in the theraphosids and others is audible to the human ear, this need not imply that these araneads have auditory organs for it is much more probable that such sounds serve only as a warning to animals other than spiders. Therefore, when all the evidence concerning the sense of hearing is summarized, I am convinced that spiders have no such sense according to our present definition of that perception.

B. THE TACTILE HAIRS.

Morphologically there are probably five or six different kinds of hairs on the various parts of the bodies in different species of araneads. Physiologically, as far as we know, they may be divided into the spinning hairs located on the spinnerets and the tactile hairs which include all others found elsewhere. The latter group includes the large movable spines, the so-called auditory hairs and the various types of tactile hairs.

While searching for the sense cells of the lyriform organs, I was successful also in finding the innervation of two kinds of tactile hairs and the muscles which move one of these. The ones without muscles I shall call fixed tactile hairs and those with muscles movable tactile hairs. In diameter the movable hairs are the second largest of all kinds of hairs and in length they are either as long but usually longer than any other type of hair; in *Theridium tepidariorum* they are abundantly distributed on the four distal joints of each leg, but rather sparingly on the other three joints of the legs and elsewhere, while on the femur most of them are located at the distal end arranged in two circular rows on the two lines of articulation. While these hairs are long, slender, more or less bent and can be moved only slightly, the movable spines are generally short, thick, straight and can be moved considerably. The former are certainly only a modification of the latter.

Fig. 7, from the trochanter of *Pholcus*, exhibits the complete innervation of the fixed tactile hairs. The socket (sk.) here, as in other cases where no muscles were observed, is like those of the movable hairs. The nerve (N.) is considerably torn, but still the parts are very

distinct. A process of the neurilemma (neu.) encloses the nerve fiber (n. f.) which runs to the sense cell (s. c.) lying at the base of the hypodermis. After the neurilemma passes around this sense cell it can no longer be seen, but the delicate sensory fiber (s. f.) continues to the socket. The sense cell at the right is much smaller and the neurilemma seems to stop before it surrounds the cell. Fig. 6, from the distal end of the femur of *Th. tepidariorum* six or seven hours after moulting, shows the actual union of the sense cell (s. c.) with the base of the movable hair. Here the sensory fiber (s. f.) ends in the cavity of the hair very near the bottom. This sense cell is similar to those of the lyriform organs, but is more difficult to find. In this section only fragments of the two muscles (m.) were discernible, and the hypodermis (hyp.) is pulled away from the newly formed cuticula (cu.). Fig. 8, from the same section as fig. 6, is a better representation of the socket and muscles, but the sense cell was not present. Here the apparently smooth muscles are attached at one end to the bottom of the flask (fl.) of the socket and at the other end to the basement membrane (b. m.) of the hypodermis. The sensory fiber is very indistinct here. The cytoplasmic substance (cyt. s.) exhibited in the cavity of this hair was observed in another hair of the same individual. It has the same color as has the sensory fiber, but instead of its walls being smooth, they are corrugated. Thus this substance must be dead cytoplasm and not a continuation of the fiber into the cavity. In the cross sections of the smaller fixed tactile hairs the sockets were always similar to those drawn, but in only one case did I see the sense cell, and in no instance did I ever see any signs of the muscles.

One can easily illustrate that the largest hairs and particularly the spines on the legs of any spider are movable by gently touching them with a small object. Before being touched they form an angle of about twenty degrees with the leg; at the instant of being irritated they lie down almost flat on the leg, the spider either lifts its leg or moves away and in only a few seconds the hairs are raised again to their normal position. Perhaps the movable spines serve primarily as a protective purpose in guarding off enemies and various kinds of obstacles, while probably the movable tactile hairs are used primarily as tactile instruments which receive the impulses of gusts of wind and the heavy vibrations of the webs, and the various kinds of smaller tactile hairs with their nervous connections receive and transmit the more delicate tactile stimuli.

Dahl (1883) called the slenderest and probably the most delicate

of the tactile hairs on the legs and palps auditory hairs, because they responded to the vibrations of a violin. Wagner (1888) described and gave drawings of four different kinds of hairs. His type called the "poil tactil fin" seems to correspond very closely to Dahl's auditory hair. Wagner showed that each type has a nerve fiber running out from its base. He said that the function of these different types cannot be recognized as identical and that no one of them can be regarded as an auditory organ. But if their function is not identical, the similarity of their fundamental parts as compared with each other and with Dahl's auditory hair causes one to conclude that they have an analogous function. Neither one of the above observers has seen the sense cells or muscles of any one type of these tactile hairs.

McCook (1890), in discussing the so-called auditory and tactile hairs, thought that all the various types should be regarded as tactile only and that perhaps each type has a particular tactile function to perform, but not an auditory one as Dahl thought.

Gaubert (1890) stated that the tactile hairs are moved by turgescence and that they possess no muscular fibers. In (1892) he asserted that the short curved spines of spiders are innately movable and serve as a strong defense by projecting outward when the araneid is seized. In discussing the blood pressure he stated that the joints are stretched by turgor, which also moves the tactile hairs.

Both Gaubert (1892) and Hansen (1893) have found tactile hairs in certain species of scorpions. The latter author described two kinds of sensitive hairs in various species of the pedipalps, and tactile hairs are found in all genera known to him in the pseudoscorpions. Hansen and Sörensen (1904), pp. 39 and 130) state that sensitive hairs are present in the phalangids and ricinulei.

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EXPLANATION OF PLATES XXX-XXXIII.

All figures are from camera lucida drawings made at the base of the microscope.

ABBREVIATIONS.

ag. cyt.....	aggregations of dense staining cytoplasm.	di.....	dilatation.
art.....	artery.	ex. m.....	extensor muscle.
b.....	border.	fl.....	flask of socket.
b. c.....	blood corpuscles.	hyp.....	hypodermis.
b. m.....	basement membrane of hypodermis.	int. b.....	internal border.
b. m. n....	nuclei of basement membrane.	l. o.....	lyriform organ.
b. p.....	blood plasm.	m. b.....	muscle bundle.
ca.....	cavity of hair.	m. nuc....	muscle nuclei.
con. t.....	connective tissue.	mov. h....	movable tactile hair.
con. t. n....	connective tissue nuclei.	N.....	nerve of leg.
cu.....	cuticula.	N. b.....	nerve branch.
cyt. s.....	cytoplasmic substance.	n. f.....	nerve fiber.
		neu.....	neurilemma.
		n. neu....	nuclei of neurilemma.

neu. n.....neuroglia nuclei.	s. f.....sensory fiber.
neu. w.....neuroglia walls.	sk.....socket.
nuc. c.....nuclei of hypodermal cells.	sl.....slit.
o. m.....outer membrane of hypo- dermis.	s. s.....single slit.
r. m.....reflexor muscle.	t. h.....fixed tactile hair.
sar.....sarcolemma.	v. sin.....venous sinus.
s. c.....sense cell.	1. l. a.....first line of articulation.
s. c. n.....sense cell nucleus.	2. l. a.....second line of articulation.

PLATE XXX.—Fig. 1.—Cross section of distal end of trochanter of *Agalena navia* just moulted, showing the anatomy of the leg and the innervation of a large lyriform organ. The cuticula is only diagrammatic as taken from various species. The nerve is drawn at the location it holds when its branch penetrates the basement membrane of the hypodermis, although this branch begins to leave the nerve 220 microns in front of this place. The sense cells have their natural position, but they have been reconstructed from nine sections just in front of where the nerve branch enters the hypodermis. All other parts are taken from just one section in front of the organ. Leitz oc. 2 and obj. 7. $\times 290$.

Fig. 2.—Diagram of a longitudinal-transverse section of the distal end of the femur of *Th. tepidariorum*, showing the anatomy of the leg and the innervation of the following: a lyriform organ, a fixed tactile hair, a movable tactile hair, and the two muscles of the latter hair. All the larger hairs are more or less movable, while the smaller ones are non-movable.

PLATE XXXI.—Fig. 3.—Two sense cells as they actually appear in a cross section of a trochanter of *Th. tepidariorum* six or seven hours after moulting. Zeiss comps. oc. 6 and oil imm. 12. $\times 960$.

Fig. 4.—Diagram showing a single slit of a lyriform organ with its sense cell attached at the bottom of the dilatation.

Fig. 5.—Reconstruction from two consecutive sections of the trochanter of *Th. tepidariorum* six or seven hours after moulting, showing the innervation of a single slit. Zeiss comps. oc. 6 and oil imm. 12. $\times 960$.

Fig. 6.—The innervation with fragments of two muscles of a movable tactile hair from the distal end of the femur of *Th. tepidariorum* six or seven hours after moulting. The hypodermis is pulled away from the cuticula. Leitz oc. 4 and obj. 7. $\times 720$.

Fig. 7.—The innervation of two fixed tactile hairs on the trochanter of *Pholcus*. The nerve is considerably torn. Leitz oc. 2 and obj. 7. $\times 455$.

Fig. 8.—Same as fig. 6, except a much smaller hair. Here the muscles are distinctly shown, but the sense cell is absent. Zeiss comps. oc. 6 and oil imm. 12. $\times 960$.

PLATE XXXII.—Fig. 9.—a ventral and b dorsal surface of the palp of a male *Troglhyphantes*, showing the single slits on the sixth joint. The bulb with its accessories are omitted. Leitz oc. 2 and obj. 3. $\times 50$.

Fig. 10.—Organ No. 13 on metatarsus of second leg of *Th. tepidariorum*. Figs. 10-12 and 15-58. $\times 385$. Zeiss comps. oc. 6 and Leitz obj. 7.

Fig. 11.—The extremely large organ on cheliceron of *Moggridgea*.

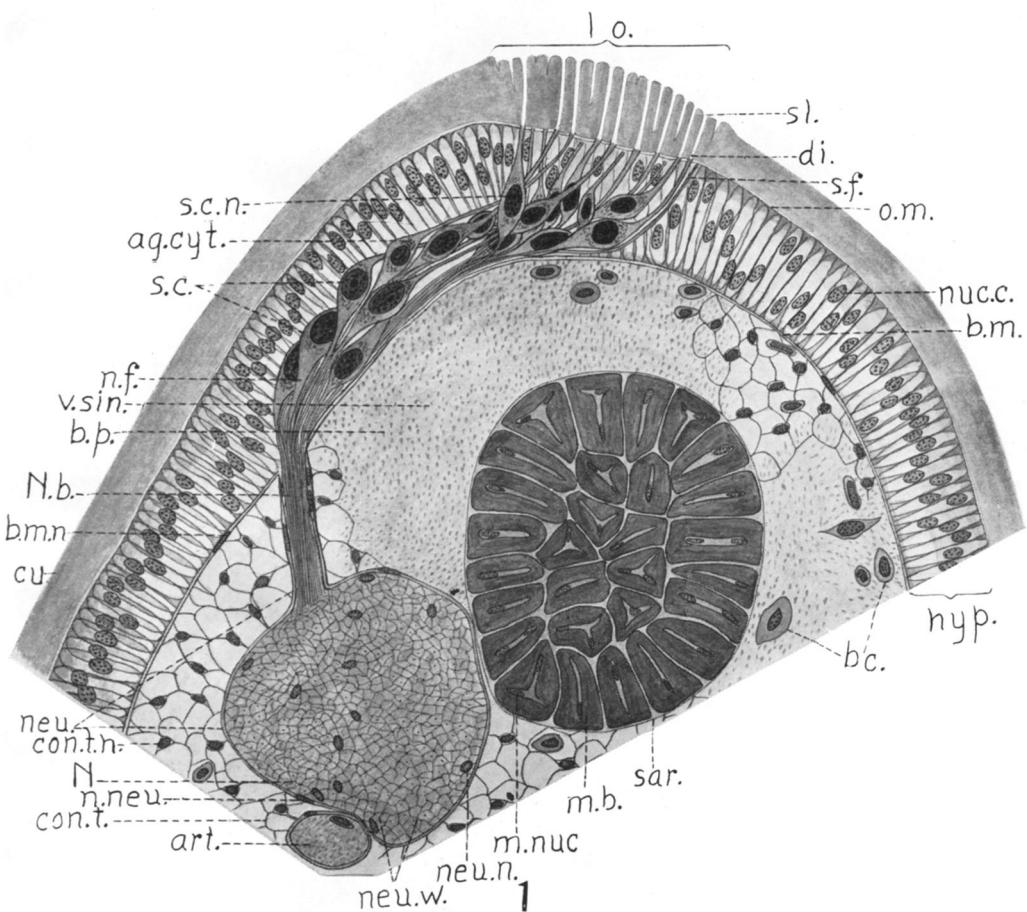
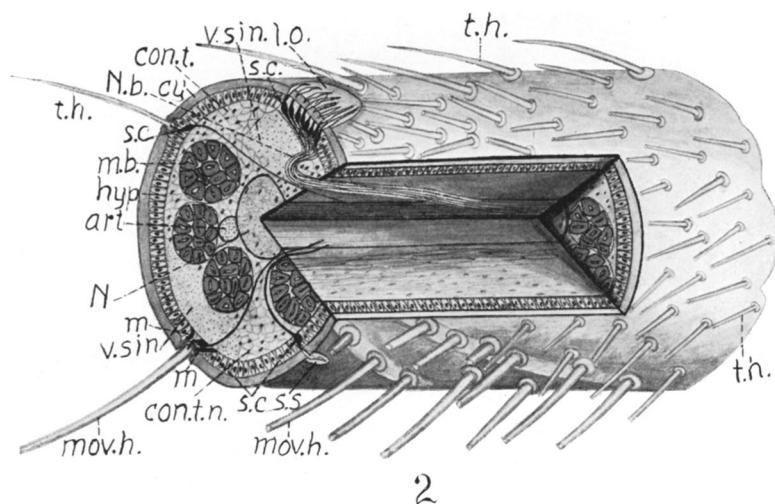
Fig. 12.—Organ on tibia of third leg of *Uroctea*.

Fig. 13.—Ventral view of *Th. tepidariorum*, showing disposition of lyriform organs. The legs are slightly too short and the last two pairs are turned over so that their dorsal surface is shown. The spider is enlarged about five, while the lyriform organs are enlarged about seven times.

Fig. 14.—Same as fig. 13, except here the dorsal view is shown and the last two pairs of legs are turned over so that they show their ventral surface.

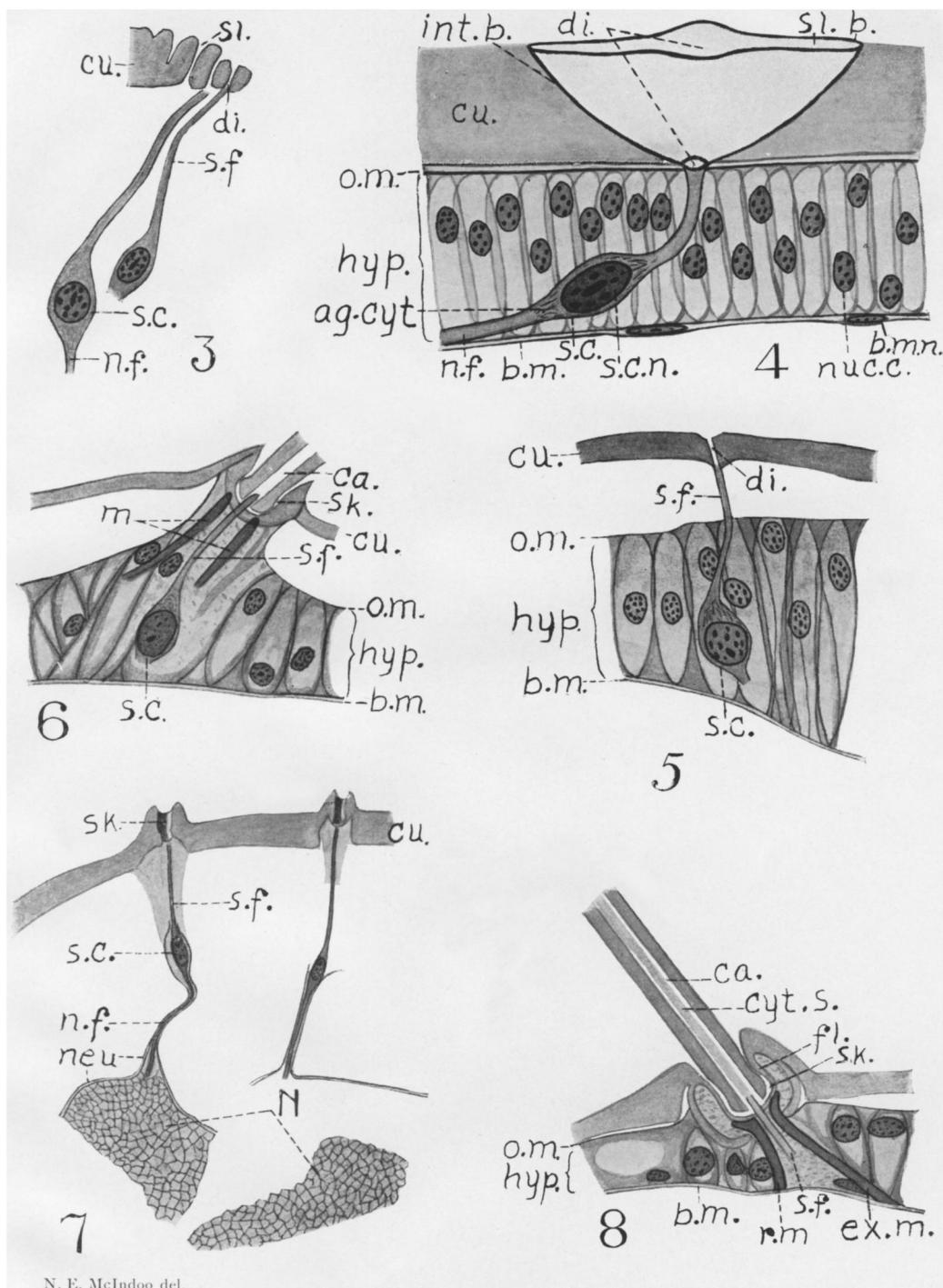
PLATE XXXIII.—Fig. 15.—Organ No. 3 from trochanter of fourth leg of *Th. tepidariorum*.

Fig. 16.—Simple organ No. 1 from coxa of first leg of *Th. tepidariorum*.
 Fig. 17.—Organ No. 9 on patella of palp of *Th. tepidariorum*.
 Fig. 18.—*b* organ No. 9 and *a* its associated slit on patella of second leg of *Th. tepidariorum*.
 Fig. 19.—Simple organ on spinneret of *Epeira*.
 Fig. 20.—Organs Nos. 14 and 15 on cheliceron of *Hyptiotes*.
 Fig. 21.—Slits from labium of *Ariadna*.
 Fig. 22.—Slits from female *Pholcus* near epigynum.
 Fig. 23.—Organ No. 8 on patella of palp of *Th. tepidariorum*.
 Fig. 24.—Organ No. 5 on femur of second leg of *Th. tepidariorum*.
 Fig. 25.—Organ on fifth joint of palp of *Moggridgea*.
 Fig. 26.—Organ No. 2 on trochanter of palp of *Th. tepidariorum*.
 Fig. 27.—Organ No. 1 on coxa of palp of *Th. tepidariorum*.
 Fig. 28.—Organs No. 16 and 17 on cheliceron of *Dictyna*.
 Fig. 29.—Single slits with hairs on first joint of spinneret of *Evagrus*.
 Fig. 30.—Organ No. 4 from trochanter of third leg of *Th. tepidariorum*.
 Fig. 31.—Single slit marked *a* in figs. 13 and 14.
 Fig. 32.—*a* is single slit marked *c* on legs; *b* is the slit marked *c* on ventral side of palp; *c* is slit called *d* on dorsal side of palp. See figs. 13 and 14.
 Fig. 33.—Compound organ on spinneret of *Tama*.
 Fig. 34.—*a* is slit called *e* on palp; *b* is slit marked *l* on palp; *c* is slit marked *j* on first leg. See figs. 13 and 14.
 Fig. 35.—Organ No. 1 on coxa of third leg of *Moggridgea*.
 Fig. 36.—Slits from pedicle of *Moggridgea*.
 Fig. 37.—*a* is slit marked *m* on first leg; *b* is slits on same leg in figs. 13 and 14.
 Fig. 38.—Organ No. 5 on femur of palp of *Th. tepidariorum*.
 Fig. 39.—Slits marked *h* on maxilla in fig. 13.
 Fig. 40.—Transverse organ on fifth joint of palp of *Moggridgea*.
 Fig. 41.—Organ No. 18 on pedicle of *Th. tepidariorum*.
 Fig. 42.—Slits marked *i* on sternum in fig. 13.
 Fig. 43.—Two organs in front of epigynum of *Calculus*.
 Fig. 44.—*a* is slit marked *j* near epigynum; *b* is slits *k* on spinneret in fig. 13.
 Fig. 45.—Organ No. 12 on tibia of second leg of *Th. tepidariorum*.
 Fig. 46.—Slits from cephalothoracic shield of *Ariadna*.
 Fig. 47.—Organ with two isolated slits in front of epigynum of *Dysdera*.
 Fig. 48.—Organ on fifth joint of palp of *Moggridgea*.
 Fig. 49.—Organ on tarsus of second leg of *Hypochilus*.
 Fig. 50.—Slits marked *g* on cheliceron of fig. 13.
 Fig. 51.—*a* and *b* organs 14 and 15, respectively, on cheliceron of *Th. tepidariorum*.
 Fig. 52.—Organ No. 2 from trochanter of first leg of *Th. tepidariorum*.
 Fig. 53.—Organ No. 2 from trochanter of second leg of *Th. tepidariorum*.
 Fig. 54.—Slits near epigynum of *Moggridgea*.
 Fig. 55.—*a* and *c* organ No. 16 and its associated slit; *b* No. 17 on cheliceron of *Th. tepidariorum*.
 Fig. 56.—Organ on fifth joint of palp of *Moggridgea*.
 Fig. 57.—*a* and *b* organs Nos. 10 and 11, respectively, from tibia of second leg of *Th. tepidariorum*.
 Fig. 58.—*a* organ No. 7 and *b* No. 8 on patella of third leg of *Th. tepidariorum*.



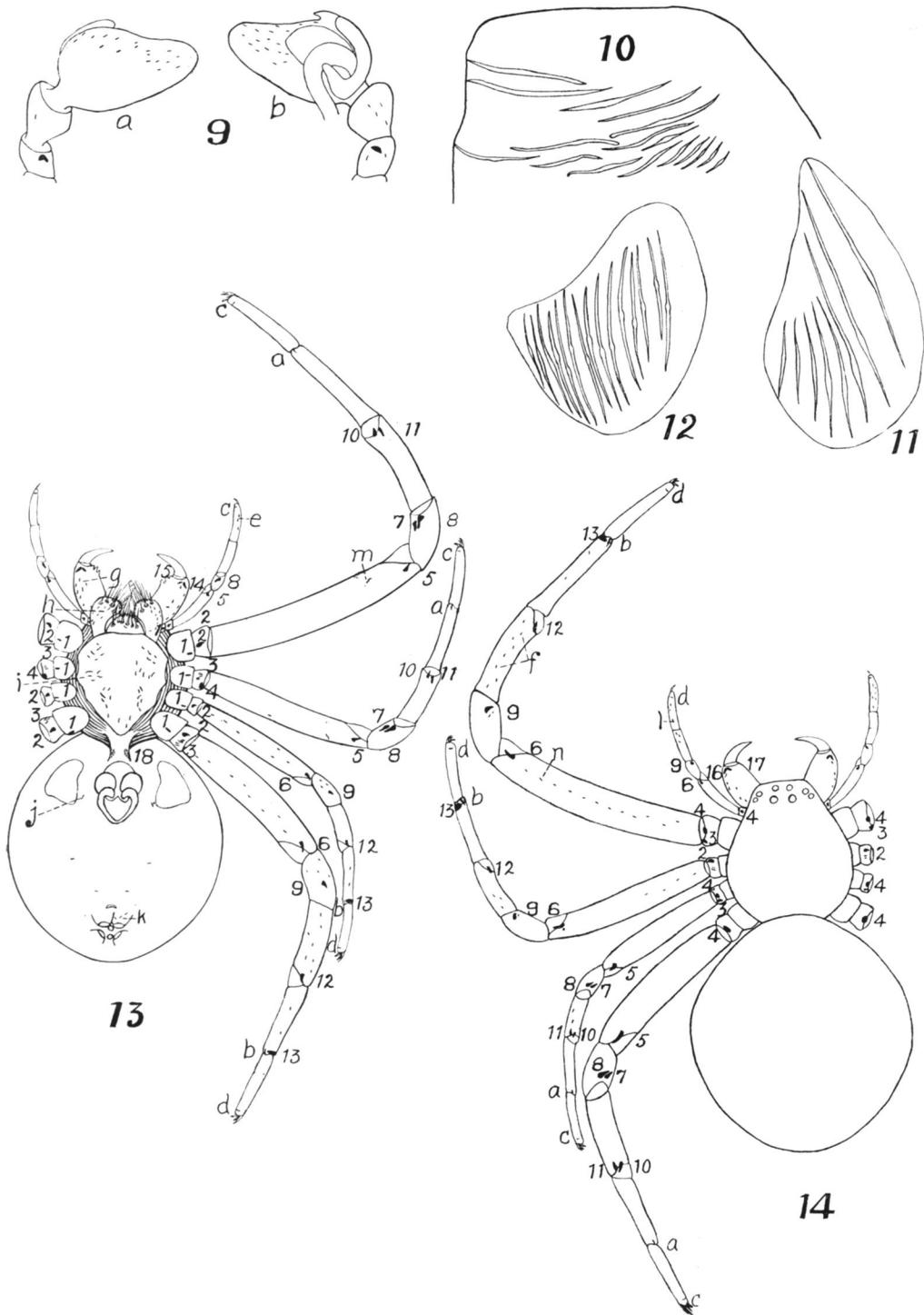
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McINDOO: LYRIFORM ORGANS AND TACTILE HAIRS OF ARANEADS.



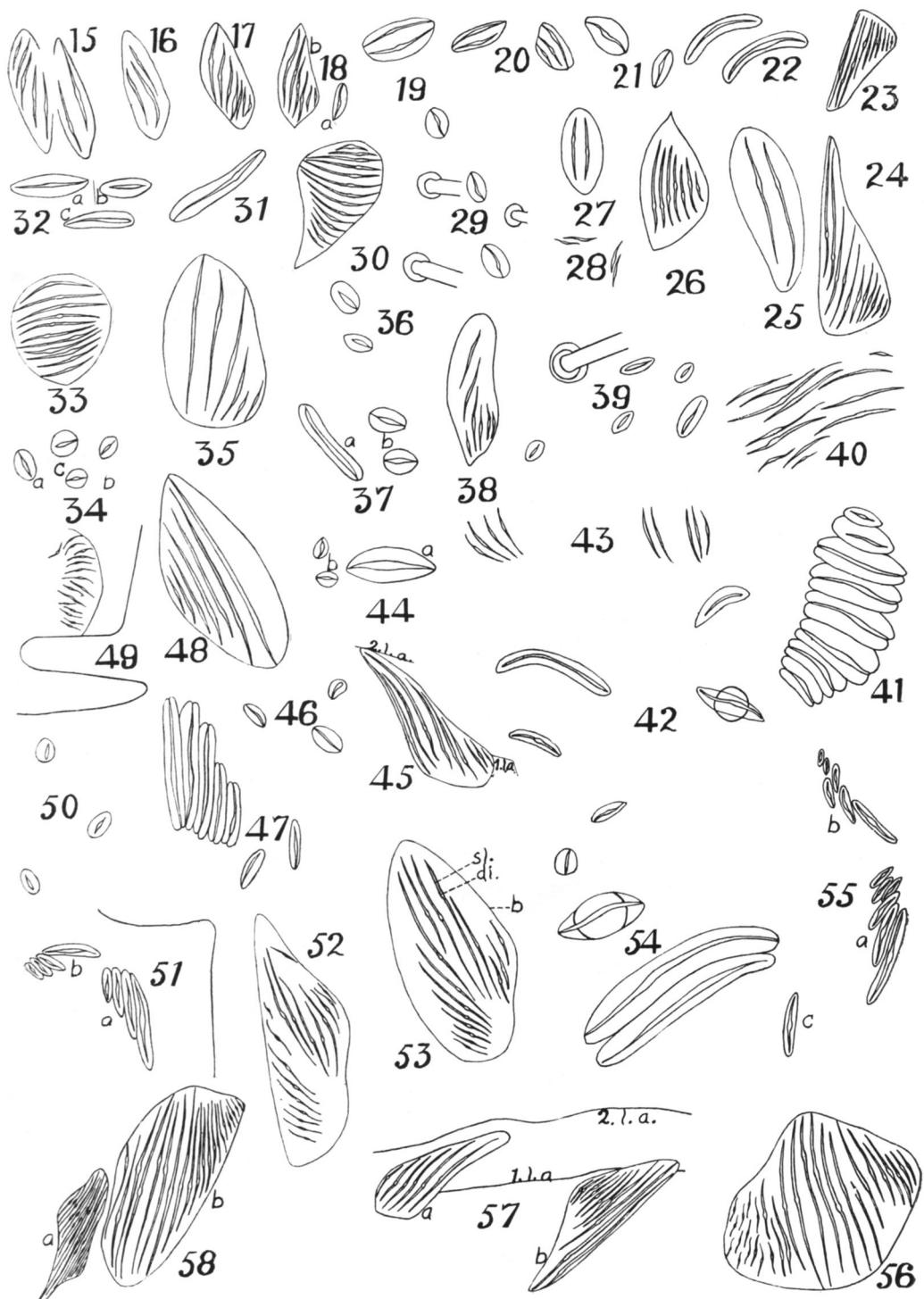
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